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Bulletin No. 358 - The Rainbow Trout in Relation to the Other Fish in Fish Lake

William F. Sigler

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by William F. Sigler[1]

INTRODUCTION

THE COAST RAINBOW *Salmo gairdnerii irideus* Gibbons is not indigenous to Utah. Its original range is Pacific North America from Alaska to Mexico. The coast rainbow was first introduced into Utah in 1883 from McCloud River, California.

The rainbow is used more extensively for artificial propagation than any other trout in North America, both for sport fishing and as a commercial food fish. Its natural habitat is big lakes and rivers; it can adapt itself to relatively small ponds, but it does not reproduce in these ponds.

Limnological and fishery investigations on Fish Lake were initiated in 1922 and have continued irregularly until the present. These investigations have been carried on cooperatively by the Utah Fish and Game Department, the Utah Cooperative Wildlife Research Unit[2], the Wildlife Management Department of Utah State Agricultural College, and the U. S. Bureau of Fisheries, now part of the United States Fish and Wildlife Service. Past work has been in three major areas: limnological studies, food habits, and creel census. This paper discusses the highlights of these three phases and the life history of the coast rainbow.

DESCRIPTION OF THE AREA

FISH LAKE, in the mountains of Sevier County, Utah, lies at an elevation of 8,800 feet above sea level. The lake occupies a graben, but it is dammed at the north end by a glacial moraine from a side valley (Hardy and Muessig, 1952). The Fish Lake watershed, part of the Colorado River system, is dominated pri-

[1]Professor and head of the Department of Wildlife Management, Utah State Agricultural College.

[2]Utah Fish and Game Department, Wildlife Management Institute, Utah State Agricultural College, and U. S. Fish and Wildlife Service, cooperating.

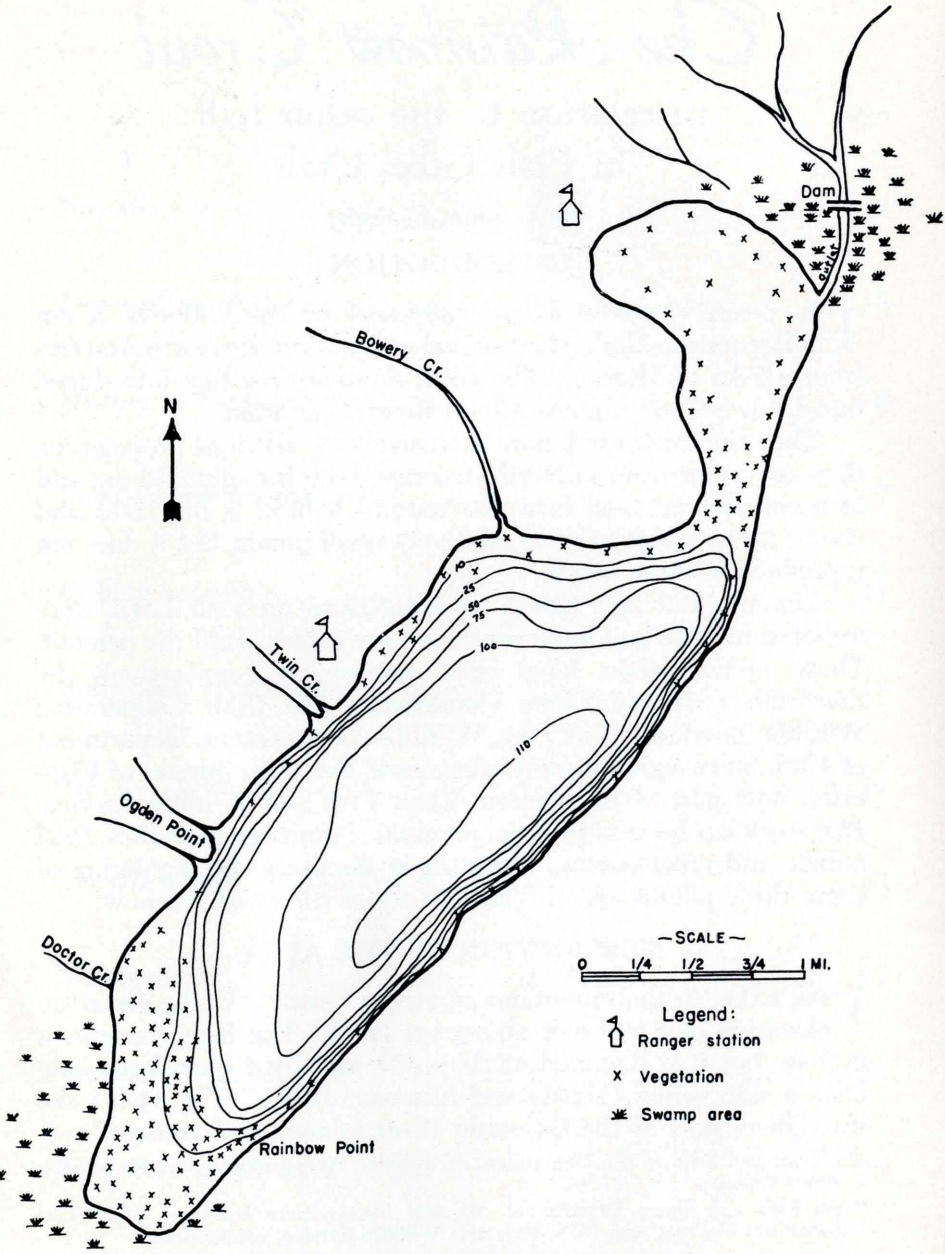


Fig. 1. Contour map of Fish Lake. Soundings made by A. S. Hazzard and Lee Kay. Map revised from U. S. Forest Service map of 1925 by M. J. Madsen

marily by spruce, aspen, and sagebrush. The area on the southwest side of the lake is a precipitous, heavily wooded rocky area that is in direct contrast to the gently sloping hills of the northeast side and the marshy areas at both ends.

Oligotrophic Fish Lake is rich in the extensive shoal areas at each end. It has a food-producing area roughly bounded by the 30-foot contour line; extending out from this zone to about the 75-foot contour line is another food producing area in which algae is plentiful. Hazzard (1935) lists the following plants as being common to abundant: *Anacharis* sp. (5-10 feet), *Zannichellia* sp. (5-10 feet), *Potamogeton* sp. (8-25 feet), *Myriophyllum* sp. (8-25 feet), *Ceratophyllum* sp. (8-25 feet), *Lemna* sp. (surface), and the two algae *Chara* sp. (10-75 feet) and *Nostoc* sp. (0-60 feet). Six spring-fed streams enter the lake on the northeast side. These streams are the only ones large enough to provide anv stream spawning grounds for trout from the lake.

The longest axis of Fish Lake lies in a northeast-southwest direction, and is 5¼ miles in length (fig. 1). The average width is about three fourths of a mile. The average depth of the lake is approximately 85 feet, and the area is roughly 2500 acres. About 70 percent of Fish Lake is more than 90 feet deep. The maximum recorded depth is 117 feet (Hazzard, 1935).

According to Hazzard (1935) a Secchi disk was visible at a depth of from 40 to 45 feet on July 23, 1935. The dissolved oxygen in 1935 ranged from 6.5 to 10.7 parts per million in water 100 feet or less in depth. The oxygen in 103 feet of water was 2.25 parts per million and at 113 feet it was 0.9. The pH in the deep water was 6.4, and in water less than 100 feet deep 7.4 to 8.5. Fleener and Sherin[3] report a Secchi disk reading of 42 feet in 1947. The bottom material in the shallow areas is largely silt mixed with considerable quantities of decaying plants. The northeast end is blanketed with a layer of live plants and decomposing plant material that ranges in depth to four feet. Although the shallow areas are largely confined to the ends of the lake, a narrow band of shallow water lies all around the lake.

The summer surface temperature varies from 62 to 69 degrees Fahrenheit. From the surface to a depth of about 25 feet the

[3]George Fleener and Gail Sherin. Fisheries investigations at Fish Lake, Utah, fishing season 1947. Utah Cooperative Wildlife Research Unit and the Utah Fish and Game Department. 1948. 27 p. Unpublished report.

temperature of the water drops gradually. From the 25 foot level down to about 60 feet the temperature decreases markedly. Below this area of rapid change in temperature, known as the thermocline, the lake remains at a more or less uniform 40 degrees during the summer months. Fish Lake is normally frozen over from December to May.

HISTORY OF THE FISHERY

APPARENTLY only two species of fish are native to Fish Lake; these are the cutthroat trout *Salmo clarki* Richardson, and the Colorado mottled sculpin *Cottus bairdi punctulatus* (Gill). According to early reports, thousands of cutthroat trout ran up the streams in the spring to spawn. This fish has become so scarce in Fish Lake that today it constitutes less than a tenth of one percent of the creel. The original strain is probably not represented.

The introduction of the brook trout *Salvelinus fontinalis* (Mitchell), in 1906 was not immediately successful. However, it apparently did well between about 1910 and 1930, but decreased rapidly thereafter until by 1936 it had almost disappeared from the creel. To the present time (1952) the brook trout has not recovered. The rainbow, first stocked in 1915, has largely replaced the brook trout. Today more than 95 percent of the creel is made up of rainbow.

The lake trout *Salvelinus namaycush* (Walbaum), was first stocked in 1906 along with the brook trout, and like the brook trout was not immediately successful. At one time lake trout was apparently more abundant in the creel than it is today, but it has never been common. Although the relative abundance of lake trout in the creel may have dropped, it is possible that the actual numbers are as high as ever. The main attraction of the lake trout is its large size rather than its abundance.

The Utah chub *Gila atraria* (Girard), first introduced into Fish Lake in 1923, was stocked either accidently by way of the bait bucket, or intentionally to provide forage for the trout. This fish had become so abundant by 1928 that it was regarded by fly fishermen as a nuisance. Presumably the Utah chub continued to increase until 1938, at which time the U. S. Bureau of Fisheries and the Utah Fish and Game Department initiated a program of

spot poisoning with rotenone. This was apparently effective in reducing the number of chub in areas of concentration. Coincidental with the increase of the Utah chub and the rainbow, the brook trout and the cutthroat continued to decrease until now they are considered of no importance from the standpoint of sport fishing.

The brown trout *Salmo trutta* Linnaeus was first recorded in the creel in 1946. It has appeared in limited numbers since that time.

The northern largemouth bass *Micropterus salmoides salmoides* (Lacépède) was first reported from Fish Lake in 1951. It is rare and would appear to be the result of accidental stocking from the bait bucket.

The smallfin redside shiner *Richardsonius balteatus hydrophlox* (Cope), native to Utah but not Fish Lake, is uncommon.

FOOD INTERRELATIONSHIPS

SIX STUDIES of food habits during the summer months, involving a total of 272 rainbow, extended over a period of five years (table 1). In three of these studies, fish was the most important food item (Wright and Madsen[4], 1942). In 1935, 1938, and 1940, the Utah chub was taken more often than any other fish. The smallfin redside shiner was second choice among forage fish, and the sculpin was rare as food. Field notes indicate that in 1935 and thereafter, the rainbow was eaten more than any other game fish. Cutthroat trout and brook trout had disappeared from the diet before 1935. The two most important invertebrate foods were *Daphnia* sp. and *Gammarus* sp. Midge larvae were the preferred insects. Mollusks and annelids appeared regularly but in relatively small numbers.

In Birch Lake, Cass County, Michigan, rainbow trout and lake trout compete for a diet of fish and aquatic insects. The rainbow feed at the surface during June only (Leonard and Leonard, 1949). Metzelaar (1929) lists rainbow food preference in the following order: insects, crustaceans, fish, and plant material.

Lake trout in Fish Lake, particularly those weighing two or more pounds, feed primarily on fish (table 2). After the Utah

[4]Stillman Wright and Vaughn D. Madsen. Report on the fishery of Fish Lake, Utah, based on investigations in 1938, 1940, and 1941. U. S. Fish and Wildlife Service, Logan, Utah. 1942. 17 p. Unpublished report.

Table 1. *Food of 272 Fish Lake rainbow from 1922 irregularly through 1948, recorded as percentages of total volume**

	1922† to 1924	1935	1935	1938	1940	1948
Fish	5	0	39	71	47	14
Game fish	0	0	0	43	0	0
Forage fish	0	0	39	28	0	0
Invertebrates	83	67	33	17	22	43
Insects	48	5	3	2	0	13
Crustaceans	35	43	30	15	0	19
Annelids	0	0	tr.	0	0	7
Mollusks	0	19	tr.	0	0	4
Plants	12	33	28	10	28	36
Algae	1	13	22	7	0	17
Vascular plants	11	20	6	3	0	19
Miscellaneous	0	0	0	2	3	7
Number of fish	13	39	46	68	92	14
Reference	Hildbrand & Towers, 1927	Hazzard 1935	Madsen 1937	Perry‡ 1938	Madsen 1942	Beck§ 1949

*Fish were taken from June through October. The total lengths of the fish range from seven inches up.

†Cutthroat and rainbow were combined.

‡L. Edward Perry. Investigations of the fishery of Fish Lake, Utah, 1938. U. S. Fish and Wildlife Service, Logan, Utah. 1938. 25 p. Unpublished report.

§DeWayne J. Beck. Food of the rainbow and lake trout taken from Fish Lake, Utah, during the 1948 fishing season. Utah State Agricultural College, Department of Wildlife Management. 1949. 6 p. Unpublished report.

chub became abundant in the lake, it appeared frequently in the diet of lake trout. This was particularly true in 1938 when the population of Utah chub was presumably at its peak. At present Utah chub and rainbow furnish the bulk of the diet of the lake trout. It appears probable that the one of these two fish that can be captured the easier suffers the greater mortality. Such factors as daily and seasonal movement and feeding habits of rainbow and Utah chub, in addition to relative abundance, probably determine which species is first in the diet.

The Utah chub does not feed on fish according to data presented here. It should be pointed out, however, that no year around studies have been made. Like the rainbow, it feeds more

Table 2. *Food habits of the three presently dominant fish in Fish Lake from 1922 irregularly through 1948, recorded as percentages of the total volume of food items**

Species	Fish	Invertebrate	Plant	Misc.	Number in sample	Year	Reference
Rainbow over 2 lb.	84	7	7	2	15	1940	Madsen, 1942
Rainbow under 2 lb.	29	28	39	4	77	1940	Madsen, 1942
Lake trout over 2 lb	17	75	7	1	17†	1923-24	Hildebrand & Towers, 1927
	96	4	0	0	21	1935	Madsen, 1937
	95	2	2	1	34	1938	Perry, 1938‖
	95	1	1	3	43	1940	Madsen, 1942
	99	0	1	0	38	1941	Madsen, 1942
	80	12	8	0	43	1948	Beck, 1949¶
Lake trout under 2 lb.	98	2	0	0	1	1923	Hildebrand & Towers, 1927
	79	20	1	0	15	1935	Madsen, 1937
	78	14	3	5	25	1938	Perry, 1938‖
	82	18	0	0	12	1940	Madsen, 1942
	86	8	6	0	9	1941	Madsen, 1942
Utah Chub	0	69	24	7	16‡	1935	Madsen, 1937
	0	77	23	0	74§	1938	Perry, 1938‖

*Fish were taken from June through October. The total lengths of the fish range from seven inches up.
†Summarized from a more detailed table, results not weighted.
‡A field examination of an additional 275 fish gave approximately the same results.
§Results arbitrarily converted from percentages of occurrence.
‖See footnote‡, table 1.
¶See footnote§, table 1.

on *Daphnia* and *Gammarus* than on any of the other invertebrates. Algae is the second most important food item and the most important plant.

The Utah chub regularly eats much the same food as do the small game fish in Fish Lake. It eats the same items as the large game fish when there is a scarcity of small fish and large invertebrates. Whether or not there is harmful competition between the Utah chub and the game fish depends on whether the Utah chub critically reduces the food items used by both. It is doubtful that such foods as algae or *Nostoc* and *Daphnia* are measurably reduced by fish feeding on them. However, Ball and Hayne (1952) report that the volume of littoral zone food in the Third Sister Lake, Michigan, may have increased as much as three times following the removal of the fish population.

Table 3. *Species composition by percentage and success of the creel in Fish Lake, Utah, from 1922 irregularly through 1950.*

Rainbow	Cutthroat	Brown trout	Lake trout	Brook trout	Pacific salmon*	Fish per hour all species	Year	Reference
11		0	11	78	0		1922-24†	Hildebrand & Towers, 1927
81	0	0	15	4	0	.89	1938	Perry, 1938‡
93	tr.	0	3	4	tr.	1.02	1940	Madsen, 1942
94	tr.	0	4	2	tr.		1941	Madsen, 1942
93	0	0	4	3	0		1942	Brown & Winsor, 1946§
96	tr.	tr.	3	1	0	.57	1946	Brown & Winsor, 1946§
94	tr.	tr.	3	3	0	.54	1947	Fleener & Sherin, 1948‖
96	tr.	tr.	3	tr.	0	.42	1948	Beck & Zarbock, 1948¶
95	0	tr.	4	1	0	.28	1949	Daly & Wright, 1950**
95	tr.	tr.	3	1	0	.54	1950	Pechacek & Johnson, in process††

*Genus *Oncorhynchus*

†The figures represent fish collected, presumably at random, by U. S. Forest Service rangers for stomach analyses. These data are all that are available for the period before 1938. Rainbow and cutthroats were combined.

‡See footnote‡, table 1.

§DeAlton T. Brown and Luther S. Winsor. The fishing trend at Fish Lake, Utah for 1946. Utah Fish and Game Department. 1946. Unpublished report. 18 p.

‖See footnote 3.

¶DeWayne J. Beck and William M. Zarbock. Fisheries investigations at Fish Lake, Utah, fishing season 1948. Utah Cooperative Wildlife Research Unit and Utah Fish and Game Department. 1948. Unpublished report. 43 p.

**Russell Daly and Young E. Wright. Fisheries investigations at Fish Lake, Utah, fishing season 1949. Utah Cooperative Wildlife Research Unit and Utah Fish and Game Department, 1950. Unpublished report. 27 p.

††Louis S. Pechacek and Arthur Johnson. Investigation of the fishery of Fish Lake, Utah. Unpublished report.

Plants were taken more readily by rainbow in Fish Lake than by other game fish, but less than by Utah chub. The plants fed on most were *Nostoc,* several of the filamentous types of algae, and *Anacharis* and *Potamogeton.* In general the larger the game fish the more piscivorous it was. The shift from one food item to another was probably a matter of availability rather than preference.

Excluding Utah chub, forage fish are extremely scarce in Fish Lake. Consequently, during periods of low fish availability most fish, excluding lake trout, rely heavily on invertebrates and plants. The present stocking is almost entirely rainbow. However, when brook trout was also stocked in sizeable numbers it did not appear as often in the creel as rainbow.

FISHING SUCCESS

REGULAR CREEL CENSUS have been used to evaluate fishing in Fish Lake since 1938, and some additional information exists as far back as 1922 (table 3). From 1946 through 1949 rainbow made up at least 95 percent of the creel and lake trout about 4 percent. Cutthroat was the most common game fish from early times until about 1916, and brook trout dominated the catch from 1916 until 1934.

Fish per man hour has dropped steadily for the last several years in Fish Lake until at present it appears to be relatively low. However, the total number of fish taken each year is tremendous. Statistically untested estimates, based on fisherman counts from 1946 through 1948, range from 33 to 46 thousand fish harvested each year. Although the individual success of fishermen has dropped steadily, it does not necessarily follow that the number of fish taken each year has decreased. This, of course, reflects not only the productivity of the lake, but also the number stocked, and an increase in fishing pressure.

A comparison of similar studies reveals some interesting information. Mottley (1940) found that 95 percent of the 1-inch fry planted in Paul Lake, British Columbia, were lost. The yield of rainbow trout in the British Columbia area was 10 pounds per acre. Surber (1933) lists a yield of 29.7 pounds of trout per acre in Big Spring Creek, Virginia. Thorpe, Rayner, and Webster (1947) record up to 80 percent of the stocked fish from a stream

as being returned to the creel. Shetter (1947) found that for comparable sizes of fish that spring planting is more desirable than fall planting. Hazzard and Shetter (1939) calculate a success of 0.77 fish per hour, and an average recovery rate of 17.5 percent from four plantings during the open season in a Michigan stream. Fishing success on Logan River, Utah, including three impoundments, is slightly higher than on Fish Lake (Pechacek, 1950; Regenthal, 1952; Thoreson, 1949). The number of stocked fish in the Logan River creel ranges from 75 to 80 percent, an unusually high rate of recovery.

Practically all lake trout are taken by trolling near the bottom. Although this is slow, it is about the only effective method. Fishermen may troll for as long as 20 to 80 hours for one lake trout. Even then, a large percentage of the lake trout are taken by a few fishermen.

Rainbow are taken by trolling during the day and by fly and bait casting from shore in the morning and evening. In general, trolling produces the fewest rainbow per hour. Fly fishing for rainbow, which begins gradually during the first part of July and increases to the maximum during the latter part of August, is extremely productive for those who are proficient. Evening fly fishing during a new moon is more successful than that during a full moon (Wright, 1943). The best season for trolling in Fish Lake is the month of June. The better shore fishing begins about the first to the middle of August and extends through September. Fishing with a guide is more successful than without a guide. The length of the fishing day varies from 2¾ to 3¾ hours.

BODY-SCALE RELATIONSHIP

A TOTAL of 612 rainbow ranging in standard length from 71 millimeters to 647 millimeters was used to calculate the body length-scale radius relationship (table 4). All data were taken at random from fisherman catches. The lengths were measured in the same manner as that described by Carlander (1950).

The body-scale relationship for Fish Lake rainbow can be described adequately by the straight line formula

L = 0.4210526 mm. + 4.6013741 R where

L = standard length in millimeters and

R = anterior scale radius times 41.6 (table 4 and fig. 2).

Table 4. *Body-scale relationships (L/Sc) of 612 rainbow from Fish Lake, arranged according to 10 millimeter standard length intervals with all age groups and sexes combined, collected from 1931 through 1951*

Mean standard length	Mean scale measurement (x41.6)	Calculated scale radius (x41.6)	L/Sc ratio	Number of fish
175	36	38	4.9	9
186	34	40	5.5	9
196	47	43	4.2	15
206	48	45	4.3	20
216	43	47	5.0	22
225	46	49	4.9	13
237	52	51	4.6	15
245	52	53	4.7	21
254	56	55	4.5	33
265	57	58	4.6	48
274	60	60	4.6	41
285	66	62	4.3	40
296	65	64	4.6	48
305	70	66	4.4	47
315	67	68	4.7	28
326	74	71	4.4	44
336	78	73	4.3	28
348	81	76	4.3	22
358	79	78	4.5	19
366	78	79	4.7	5
373	81	81	4.6	19
384	83	83	4.6	20
395	90	86	4.4	11
404	91	88	4.4	3
417	92	90	4.5	8
425	88	92	4.8	3
435	88	94	4.9	4
447	100	97	4.5	1
468	97	102	4.8	3
494	109	107	4.5	2
506	104	110	4.9	1
516	120	112	4.3	3
524	125	114	4.2	1
533	125	116	4.3	1
541	110	118	4.9	1
566	118	123	4.8	2
580	119	126	4.9	1
647	125	140	5.2	1

L = .4210526 mm. + 4.6013741 R.

A slightly better description of the body-scale relationship is obained by using the second degree parabola

$$L = .01193 \text{ mm.} + 4.61282\ R - .000069851\ R^2.$$

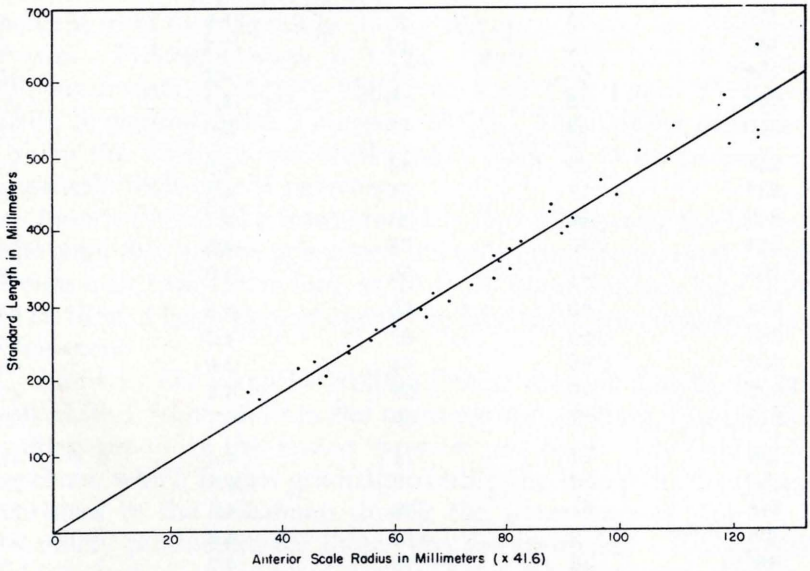


Fig. 2. Body-scale relationship of 612 rainbow trout from Fish Lake (Based on table 4)

Although the parabola corresponds more closely to the data than the straight line, it is believed that the use of this more complex formula is not warranted by the small additional accuracy it gives. Examination of the data indicated that neither sex, length, nor age has any detectable influence on the body-scale relationship. Therefore all data were combined.

AGE AND GROWTH

THE VALIDITY of the scale method of age determination for the Fish Lake rainbow was explored according to techniques set forth by Van Oosten (1929). Bhatia (1931) and many others have demonstrated the validity of the scale method for assessing ages to rainbow. It is believed that the age evaluation is reasonably accurate.

Only six streams flowing into Fish Lake are large enough for rainbow to spawn in, and the Utah Fish and Game Department

in recent years has generally taken spawn from most of the fish entering these streams. It appears there is relatively little stream reproduction, but M. J. Madsen[5] reports he has seen and collected numerous rainbow along shore which were smaller than any stocked. There is, therefore, an undetermined amount of reproduction along shore. Plantings are made throughout much of the year even under the ice. Sizes of fish planted range from fingerling to ones occasionally 16 inches long. However, the bulk of legal-length rainbow planted average about 12 inches. This variation, as the following data indicate, creates a rather unusual problem when ageing the fish and calculating the rate of growth.

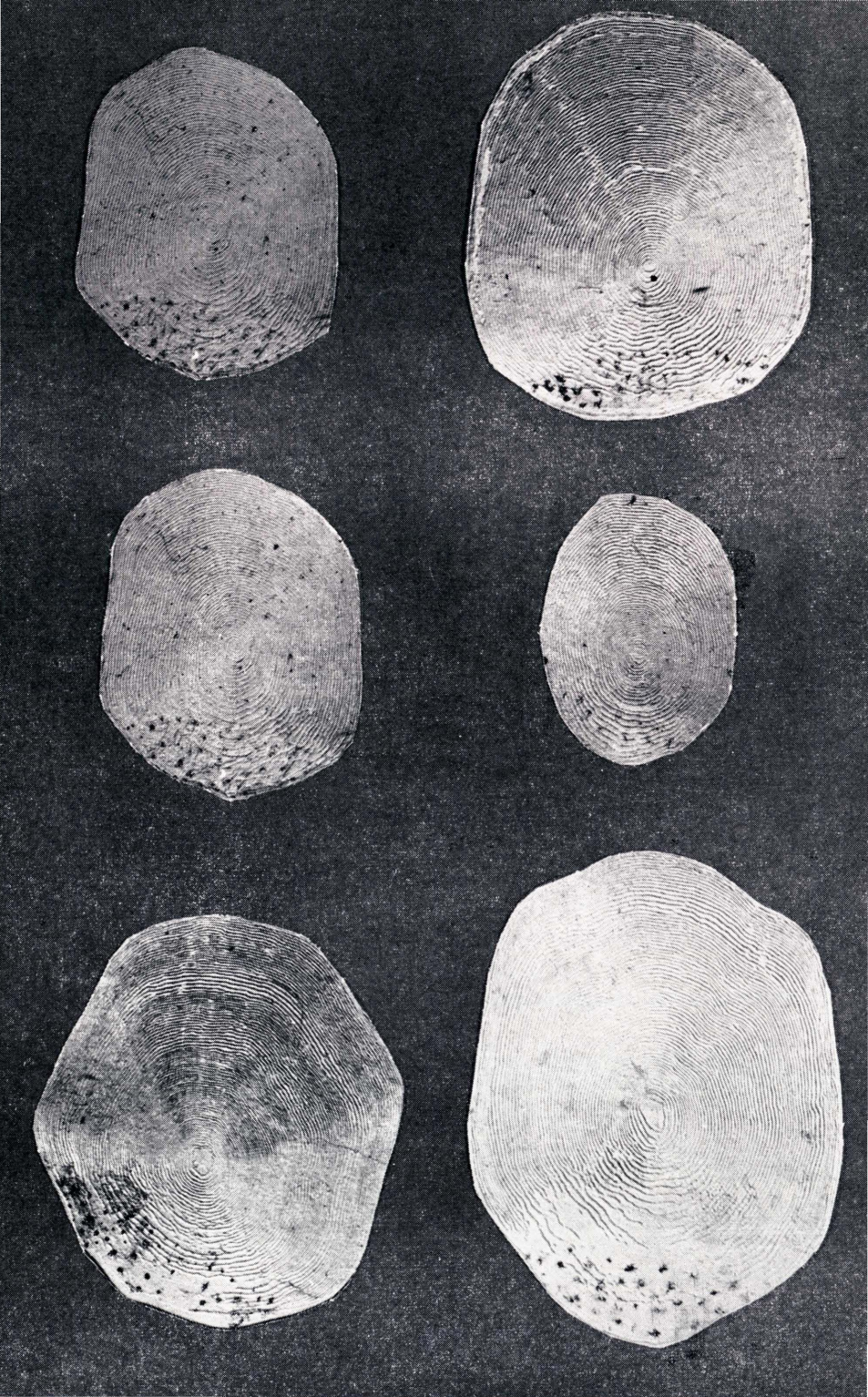
Many of the rainbow planted in Fish Lake come from the Glenwood Hatchery. In order to study the scale development of the Glenwood fish in relation to their growth, 5 collections totaling 65 fish were taken from November 1951 through May 1952. It was found that these fish, ranging in total length from 3 to 15 inches (ages 3 to 14 months) did not form a discernable annulus, and that usually the circuli were quite uniformly spaced (fig. 3).

Scales from some fish taken from the lake are so distinctive that they can be identified as those having been raised in the hatchery.

Because of its regular circuli, lack of annulus, and the large size of the fish, the scale shown in fig. 4 is judged to be from a fish that overwintered in the hatchery. The scale in fig. 5 is believed to be from a fish that grew rapidly in the hatchery and produced its first annulus near the edge, the first spring after being planted. Fig. 6 is from a slow-growing fish that either was spawned in the wild or was planted at an early age. Scales in fig. 7 and 8 have 2 and 3 annuli, respectively. Fish in the wild grow slower for the first 12 inches than those at the Glenwood Hatchery.

All fish were assessed ages based on the number of annuli or year marks on the scales. The 1-year group contained a total of 158 fish, 15 of which were judged to have been raised to a size of 11 to 15 inches in the hatchery. These fish exhibited two distinctive traits: the circuli from the focus out to the annulus were much more uniform than those of other fish, and they were markedly larger than other fish having one annulus. The average

[5]Superintendent of Fisheries, Utah Fish & Game Department, Salt Lake City, Utah.



standard length at capture of these 15 fish was 285 millimeters as compared to 229 millimeters for the other 143 fish. Since no attempt was made to differentiate hatchery overwintered fish after the first year, this group of 15 was excluded from the calculated length study (table 5). Inclusion of these fish would invalidate the age composition of the 1-year group.

The belief that Fish Lake is extremely rich in food is amply borne out by the rate at which fish grow: 4-year old rainbow were 16.4 inches long and 6-year olds were 24.3 inches long (table 5). The fish grow at a rather uniform rate of three to four inches per year. This rate of growth is much faster than most of those described in literature (Greeley, 1933; Kathrein, 1951; Purkett, 1951). There is no indication of Lee's phenomenon.

Fish in their third year of life (II-age group) are the most abundant, according to the calculated length study. These fish are between 10.2 and 13.2 inches long. Junius F. Powell[6] states the average size of fish planted is 12 inches; he further indicates that 90 percent of the returns from marked fish in 1950 were made during that same year. None of the 16 to 18 month hatchery fish and few of the II-year group in the lakes are mature. Relatively few fish in the five and six-year groups were taken. The percentage of older fish has decreased in recent years (table 6).

The calculated lengths for each year were determined by a nomograph similar to that described by Carlander and Smith (1944).

Factors for the conversion of standard, fork, and total lengths are calculated without regard to either age, sex, or length, since an examination of the data indicated that these potential variables appeared to have no appreciable effect on the results (table 7). The conversion factors of Fish Lake rainbow agree reasonably well with those from eastern streams (Klack, 1941) and New York state (Carlander, 1950).

[6]Superintendent Glenwood Hatchery, Utah Fish & Game Department, Glenwood, Utah.

Fig. 3. (Upper left) 13-inch rainbow from Glenwood Hatchery, spawned November 20, 1950; collected February 10, 1952. Fig. 4. (Upper right) 14-inch rainbow from Fish Lake, collected summer 1952. Fig. 5. (Center left) 17-inch rainbow from Fish Lake, collected summer 1952. Fig. 6. (Center right) 12-inch rainbow from Fish Lake, collected fall 1952. Fig. 7. (Lower left) 14-inch rainbow from Fish Lake, collected fall 1950. Fig. 8. (Lower right) 19-inch rainbow from Fish Lake, collected summer 1952

Table 5. *The mean calculated standard lengths and annual increments of length in millimeters for rainbow from Fish Lake with sexes combined, collected irregularly from 1931 through 1951*

Age class	Number of fish	Standard length of capture	Calculated length at end of year					
			1	2	3	4	5	6
I	143	229	159					
II	205	286	136	227				
111	125	335	128	217	285			
IV	43	388	126	209	283	351		
V	9	473	136	226	296	362	436	
VI	5	578	144	234	317	406	474	531
Grand average of total	530		139	222	286	358	450	531
Increments of growth			139	90	69	70	71	57
Equiv. total length in inches			6.4	10.2	13.1	16.4	20.6	24.3

Table 6. *Age composition by collection years of 530 rainbow from Fish Lake, Utah*

Collection year	Number of fish	I	II	III	IV	V	VI
1931	4	3		1			
1935	24	7	3	6	5	2	1
1938	29	3	9	9	2	3	3
1941	81	34	38	9			
1942	2			1	1		
1945	1		1				
1948	24	3	11	8	2		
1949	130	34	39	39	14	4	
1950	105	23	50	28	4		
1951	130	36	54	24	15		1
Totals	530	143	205	125	43	9	5

LENGTH-WEIGHT RELATIONSHIP

THE MATHEMATICAL relation between the standard length in millimeters (L) and the weight in grams (W) of 251 rainbow from Fish Lake can be described by the formula Log W = –5.60804 + 3.3401629 Log L (table 8 and fig.9). These data were examined, but not treated statistically for variation caused by sex; there is little difference for the first three years; after that, the females are relatively heavier than the males. All data are combined.

The condition factor (K) is calculated by the formula

$$K = \frac{W \times 10^5}{L^3}$$

Table 7. *Factors for the conversion of standard, fork, and total lengths of rainbow from Fish Lake* (Age groups, sexes, and lengths combined)*

T. L. to S. L. (no change of units)	0.86016
T. L. (in.) to S. L. (mm.)	21.84806
S. L. to T. L. (no change of units)	1.16258
S. L. (mm.) to T. L. (in.)	0.04577
F. L. to S. L. (no change of units)	0.89768
F. L. (in.) to S. L. (mm.)	22.80107
S. L. to F. L. (no change of units)	1.11398
S. L. (mm.) to F. L. (in.)	0.04386
T. L. to F. L. (no change of units)	0.95549
F. L. to T. L. (no change of units)	1.04659

*S. L. = standard length; F. L. = fork length; T. L. = total length. Conversions involving standard length and total length are based on 396 fish; those involving fork length are based on 203 fish.

Table 8. *Length-weight relationship of rainbow from Fish Lake, based on actual lengths and weights of 251 fish collected irregularly from 1931 through 1951**

Mean standard length in millimeters	Actual mean	Calculated mean†	Difference in actual and calculated weight	Mean K	Number of fish
175	96	77	− 19	1.80	5
186	95	94	− 1	1.46	8
195	112	110	− 2	1.52	4
207	142	134	− 8	1:60	10
215	157	152	− 5	1.59	10
225	183	177	− 6	1.61	6
235	210	205	− 5	1:61	7
245	232	236	+ 4	1.64	9
255	255	269	+ 15	1.53	16
265	316	306	− 10	1.71	15
274	311	342	+ 31	1.53	16
285	373	390	+ 17	1.62	12
296	436	443	+ 7	1.67	14
305	477	490	+ 13	1.66	19
315	462	545	+ 83	1.47	14
326	553	612	+ 59	1.60	18
337	583	683	+100	1.52	14
347	739	754	+ 15	1.78	6
356	776	821	+ 45	1.71	8
365	854	892	+ 38	1.75	4
376	961	985	+ 24	1.80	7
385	1035	1066	+ 31	1.84	8
404	1070	1252	+182	1.62	2
419	1493	1414	− 79	2.04	5
425	1850	1483	−367	2.41	1
434	1618	1591	− 27	1.97	3
465	1900	2003	+103	1.89	1
494	2778	2452	−326	2.32	2
506	2627	2656	+ 29	2.03	1
516	3145	2836	−309	2.30	3
565	3629	3829	+210	2.01	1
580	4763	4191	−572	2.44	1
647	6350	6037	−313	2.35	1

*The average standard lengths are based on 10 millimeter intervals with the sexes combined.

†Based on the formula $W = .00000246558\ L^{3.3401629}$

where L = standard length in millimeters and W = weight in grams. The K factor varies from 1.46 to 2.44. It increases irregu-

larly as the length and age increase. The condition factor of Fish Lake rainbow is considerably higher than that of many of the rainbow described in literature (Schneider and Griffiths, 1943; Wales, 1946 and 1947; Klak, 1941; Carlander, 1950). It is also higher than that of the 20 Fish Lake rainbow described by Hazzard (1935).

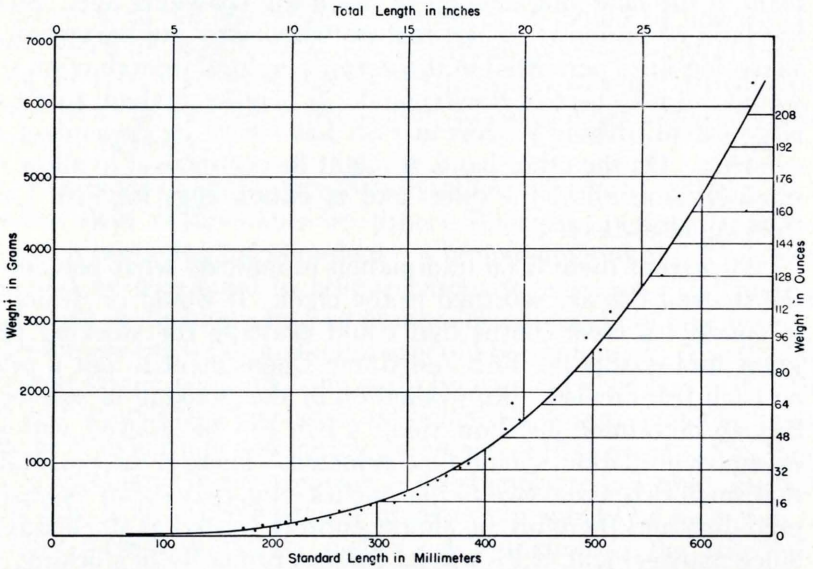


Fig. 9. Length - weight relationship of Fish Lake rainbow. Log = −5.60804 +3.3401629 Log L

MANAGEMENT

WHERE MANAGEMENT consists mainly of stocking with legal-size fish, the average catch per hour may be expected to vary with the number of fish stocked, and the number stocked is determined by the income. According to recent figures released by M. J. Madsen, the production cost of trout from the Glenwood Hatchery, excluding capital investment, is 45.9 cents per pound. This means that it takes about 34 cents, plus capital investment costs, to stock a 12 ounce fish. All stocked fish are not returned to the creel. A return of 80 percent is exceedingly high; 30 to 50 percent is probably nearer average. When all factors are considered it is not hard to see that an average cost Utah fishing license (there

are several classes) can hardly be expected to supply more than 5 or 6 stocked fish per year. More artificially reared fish obviously means a higher license fee.

The spawn take has dropped steadily during the past fifteen years in Fish Lake until there are relatively few eggs taken at present. This would appear to indicate that rainbow do not remain in the lake long enough to reach the spawning age. Since the bulk of rainbow are not mature when they are harvested, if spawning were permitted in the streams, natural reproduction still would not take care of the demand. It is quite evident, that to a large extent, fishing success in Fish Lake must be dependent on stocking. On the other hand, it might be economical to allow reproduction in all of the inlets and to obtain eggs for Fish Lake stocking elsewhere.

At present there is no information to indicate what percent of the stocked fish are returned to the creel. It would be desirable to conduct a creel census that could evaluate the stocking program, and enable the Fish and Game Department to put a price on each fish creeled. An evaluation of the stocking of sub-legal fish, to determine just how small a fish can be stocked without excessive predation, should be conducted. There is the possibility that small fish, those two to four inches long, may suffer extensive predation and therefore be almost entirely wasted as stocked fish. Since management of Fish Lake consists primarily of stocking, an evaluation of the program could be used to convince sportsmen of the impossibility of increased numbers unless the present license fee is increased.

The rainbow planted as fingerling in Fish Lake reach the legal length of seven inches in about 13 months. This conclusion is based on the fact that they reach a length of 6.4 inches at the end of the first year and grow an additional 3.8 inches the second year (table 5). The annulus is formed in April or early May, and the fishing season does not open until mid-June. This means the 1-year group is exposed to the same fishing pressure as other year groups. In many heavily fished areas the yearlings are the most abundant year group, but they are rarely legal-size. If the II-year group of rainbow in Fish Lake furnishes the greatest number of fish to the creel, it appears that further fishing pressure could be exerted without harm. However it is obvious that many fish of

this size group (10 to 13 inches long) are from the current year's plant. The fact that few fish beyond the IV-year class are taken also indicates no lack of harvesting effort.

The Utah chub along with the rainbow has been blamed for the gradual crowding out of brook and cutthroat trout. Probably to a fair extent this is true since all of these fish feed either at the surface or in the littoral zone. However, it should be pointed out that since the lake trout is almost entirely piscivorous after reaching the size of about 2 pounds, if Utah chub was not available for lake trout to feed on it would turn to some other abundant fish, notably rainbow.

The spot poisoning program should be continued on Utah chub when field observations by fishery biologists indicate that the chub is becoming too abundant. A limited amount of fall planting should be continued to relieve hatchery pressure. The present practice of stocking a limited number of sub-legal rainbow in order to increase the total production, should be continued. The fishing season should continue from early June until Labor Day. If there is no evidence that lake trout are being taken from spawning beds, there is no harm in continuing the season until the first of October. The legal limit of seven inches is satisfactory for all trout, excluding lake trout. The legal size of lake trout should be increased to either sixteen or twenty inches. A reduction in the bag limit would undoubtedly save a great many fish the first two or three days of the season. This should be seriously considered for Fish Lake if fishing pressure continues to increase.

SUMMARY

LIMNOLOGICAL and fishery investigations dealt with in this paper were initiated in 1922, and have continued irregularly until the present. The rainbow, not indigenous to Utah, is given more attention than other fish. Fish Lake, which was once a cutthroat trout lake, is now essentially a rainbow – lake trout lake. The brook trout is also following the cutthroat along the road to extirpation. The Utah chub, first introduced in 1923, has prospered.

Fish Lake is approximately 2500 acres in size and has an average depth of 85 feet. Summer temperatures vary from 62 to 69 degrees Fahrenheit. There is a thermocline.

Studies of food habits involving 272 rainbow indicate that fish is an important item, but the rainbow is able to shift from a fish diet to an invertebrate diet when small fish become scarce. Forage fish in Fish Lake, excluding Utah chub, are rare. The rainbow is eaten more than any other game fish. The Utah chub does not feed on fish during the summer but rather, primarily on small invertebrates and algae. Lake trout weighing more than two pounds feed primarily on fish.

The species composition in the creel over the years has shifted from cutthroat trout, to brook trout, to rainbow and lake trout. Rainbow, today, make up approximately 95 percent of the creel. The average size of the rainbow in Fish Lake is decreasing each year, but it appears probable that the total number is increasing. The number of fish taken per hour has decreased irregularly until at the present time, it is approximately one-half fish.

Six hundred and twelve rainbow trout ranging in standard length from 171 millimeters to 647 millimeters were used to calculate the body-scale relationship of $L = 0.4210526\ MM. + 4.6013741\ R$. The II-year group of fish is more abundant than any other year group. The rate of growth of rainbow in Fish Lake is fast. Fish, two years old, are more than ten inches long, and five-year old fish have reached a length of almost 21 inches. The number of older fish in the creel has decreased from 1931 to the present. The length-weight relationship of 251 rainbow is described by the formula, $\text{Log } W = -5.60804 + 3.3401629 \text{ Log } L$. There is little difference in the length-weight relationship of the sexes for the first three years of life.

Management of Fish Lake fish is at present largely a matter of put in and take out. The six streams large enough to support spawning fish are generally blocked off to take spawners for the state fish hatcheries. There is an unknown amount of natural reproduction along the shores of the lake. The average fishing license will probably supply not more than five or six stocked fish per year to the creel.

LITERATURE CITED

Ball, Robert C. and Don W. Hayne. Effects of the removal of the fish population on the fish-food organisms of a lake. Ecology 33:41-48. 1952.

Bhatia, D. Factors involved in production of annual zones on scales of rainbow trout. II. Jour. Exper. Biol. 9:6-11. 1932.

Carlander, Kenneth D. Handbook of freshwater fishery biology. Dubuque, Iowa, Wm. C. Brown Co., 1950. p. 4.

Carlander, Kenneth D. and Lloyd L. Smith, Jr. Some uses of nomographs in fish growth studies. Copeia 3:157-162. 1944.

Greenley, John R. The growth rate of rainbow trout from some Michigan waters. Amer. Fish. Soc. Trans. 63:361-378. 1933.

Hardy, Clyde T. and Siegfried Muessig. Glaciation and drainage changes in the Fish Lake Plateau, Utah. Geol. Soc. Amer. Bul. 65:1109-1116. 1952.

Hazzard, A. S. A preliminary study of an exceptional productive trout water, Fish Lake, Utah. Amer. Fish. Soc. Trans. 65:122-128. 1935.

Hazzard, Albert S. and David S. Shetter. Results from experimental plantings of legal-sized brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo irideus*). Amer. Fish. Soc. Trans. 68:196-210. 1939.

Hildebrand, S. F. and I. L. Towers. Food of trout in Fish Lake, Utah. Ecology 8. 4:389-397. 1927.

Kathrein, Joseph W. Growth rate of four species of fish in a section of the Missouri River between Holter Dam and Cascade, Montana. Amer. Fish. Soc. Trans. 80:93-98. 1951.

Klak, George E. The condition of brook trout and rainbow trout from four eastern streams. Amer. Fish. Soc. Trans. 70:282-289. 1941.

Leonard, J. W. and F. A. Leonard. An analysis of the feeding habits of rainbow trout and lake trout in Birch Lake, Cass County, Michigan. Amer. Fish. Soc. Trans. 76:301-314. 1949.

Madsen, Clyde R. A study of the fish foods of Fish Lake, Utah. Utah State Agricultural College, B. S. thesis, 1937. 34 p.

Madsen, Vaughan D. Investigations of the fishery of Fish Lake, Utah. Utah State Agricultural College, M. S. thesis, 1942. 62 p.

Metzelaar, Jan. The food of the trout in Michigan. Amer. Fish Soc. Trans. 59:146-152. 1929.

Mottley, C. McC. The production of rainbow trout at Paul Lake, British Columbia. Amer. Fish. Soc. Trans. 69:187-191. 1940.

Pechacek, Louis S. Harvest of wild and stocked fish from the Logan River drainage. Utah State Agricultural College, M. S. thesis, 1950. 103 p.

Purkett, Charles A., Jr. Growth rate of trout in relation to elevation and temperature. Amer. Fish Soc. Trans. 80:251-259. 1951.

Regenthal, Albert F. A method of estimating fishing pressure and harvest as used on Logan River, Utah. Utah State Agricultural College, M. S. thesis, 1952. 45 p.

Schneider, Phillip W. and Francis P. Griffiths. Production of trout in a small artificial pond in western Oregon. Jour. Wildlife Mgt. 7:148-154. 1943.

Shetter, David S. Further results from spring and fall plantings of legal-sized, hatchery-reared trout in streams and lakes of Michigan. Amer. Fish. Soc. Trans. 74:35-58. 1947.

Surber, Eugene W. A quantitative study of rainbow trout production in one mile of stream. Amer. Fish. Soc. Trans. 63:251-256. 1933.

Thoreson, Nels A. An evaluation of trout stocking in the Logan River drainage. Utah State Agricultural College, M. S. thesis, 1949. 56 p.

Thorpe, Lyle M., H. John Rayner, and Dwight A. Webster. Population depletion in brook, brown, and rainbow trout stocked in Blackledge River. Connecticut, in 1942. Amer. Fish Soc. Trans. 74:166-187. 1947.

Van Oosten, John. Life history of the lake herring (*Leucichthys artedi* LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. U. S. Bur. Fish. Bul. 44 (Doc. 1053): 265-428. 1929.

Wales, J. H. Castle lake trout investigations. First phase: Interrelationships of four species. Calif. Fish and Game 32.3:109-143. 1946.

Wales. J. H. Castle lake trout investigations: 1946 catch and chemical removal of all fish. Calif. Fish and Game 33.4: 267-286. 1947.

Wright, Stillman. The effect of moonlight on fishing success in Fish Lake, Utah. Amer. Fish. Soc. Trans. 73:52-58. 1945.